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State change in the polar regions

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Call for evidence and Terms of Reference: https://committees.parliament.uk/call-for-evidence/3503/

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Authors

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Bethan Davies is a Professor of Glaciology at Newcastle University. She specialises in the response of glaciers and ice sheets to climate change. She researchers how ice masses behave in different climates and environments, with recent work focusing on the British-Irish Ice Sheet, Patagonia, Antarctica, the Andes, Alaska, Svalbard, and Austria. She uses empirical observations to improve projections of future glacier behaviour and to understand the drivers of past and present glacier change.

Huw Griffiths

Dr Huw Griffiths has worked as a marine biologist for British Antarctic Survey for over 20 years, studying the animals that live at the bottom of the sea around Antarctica and the Arctic. He also studies the potential effects of marine protected areas, climate change, human impacts and pollution on these unique ecosystems, and has participated in and led multiple expeditions to both poles, studying everything from the beaches to the deep sea.

Klaus Dodds

Klaus Dodds is Professor of Geopolitics and Executive Dean at the School of Life Sciences and Environment at Royal Holloway University of London. His areas of expertise include polar geopolitics and strategy and border disputes. His recent books include *Border Wars* (Penguin 2022) and is currently working on a co-authored book on Arctic geopolitics for Yale University Press. He has in the recent past acted as a specialist adviser to the UK Parliament and worked with NATO's Strategic Foresight Analysis group.

1. What are the most significant environmental changes taking place in the Antarctic?

Polar ice sheets

Antarctica is world's largest ice sheet and comprises a thick mass of ice surrounded by ice shelves (the floating seaward extensions of land ice) and sea ice (frozen sea water), surrounded by the Southern Ocean.

The sea level equivalent (the amount that global sea levels would rise, on average, if the Antarctic Ice Sheet melted) for Antarctica is 57.9 m [1].

The Antarctic Ice Sheet contains three distinct parts. The UK's overseas territory, British Antarctic Territory, is defined largely around the smaller Antarctic Peninsula. The latter is a spine of smaller mountain glaciers, terminating in the ocean or in floating ice shelves, and much of the ice, usually only a few hundred metres thick, is grounded on land above sea level (Figure 1, Figure 2). The Bellingshausen Sea is one of the few places where the ice is grounded significantly below sea level.

The largest ice sheet is the East Antarctic Ice Sheet, which is largely grounded above sea level, except for some large marine basins. Ice here can reach up to 4,000 m thick [1] (Figure 1). Finally, the Transantarctic Mountains transect the continent, separating the East and the West Antarctic Ice Sheet. The West Antarctic ice Sheet is largely grounded well below sea level; if the land ice disappeared, West Antarctica would look like a series of islands, rather like Indonesia today. This makes West Antarctica sensitive to marine melting and susceptible to rapid recession of the grounding line. Increased ice discharge and increased icebergs could make shipping in these areas more difficult in coming decades.

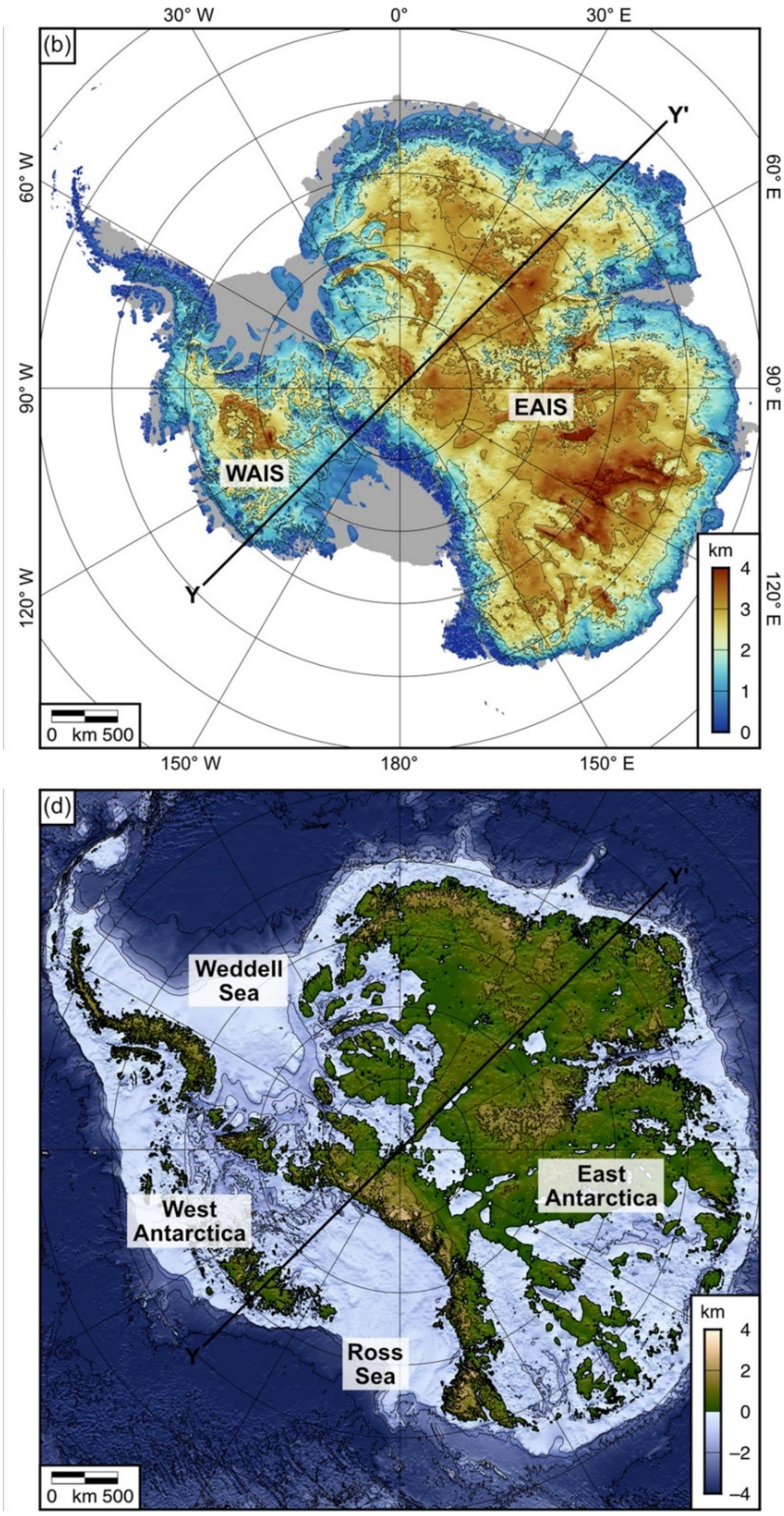

Figure 1. Ice thickness (a, b) and bed topography (c, d) of Antarctica and Greenland [2].

Mass loss from the Antarctic Ice Sheet

Today, the Antarctic Ice Sheet is losing mass, with most of the ice loss from West Antarctica and being lost through melting and iceberg calving [3]. This is largely attributed to ocean heating, with most ice loss concentrated in the Amundsen Sea [4] (Figure 2; Figure 3). Mass loss has increased in recent decades (Figure 3). UK and collaborative international science, notably the International Thwaites Glacier Project, have been particularly crucial in quantifying these processes.

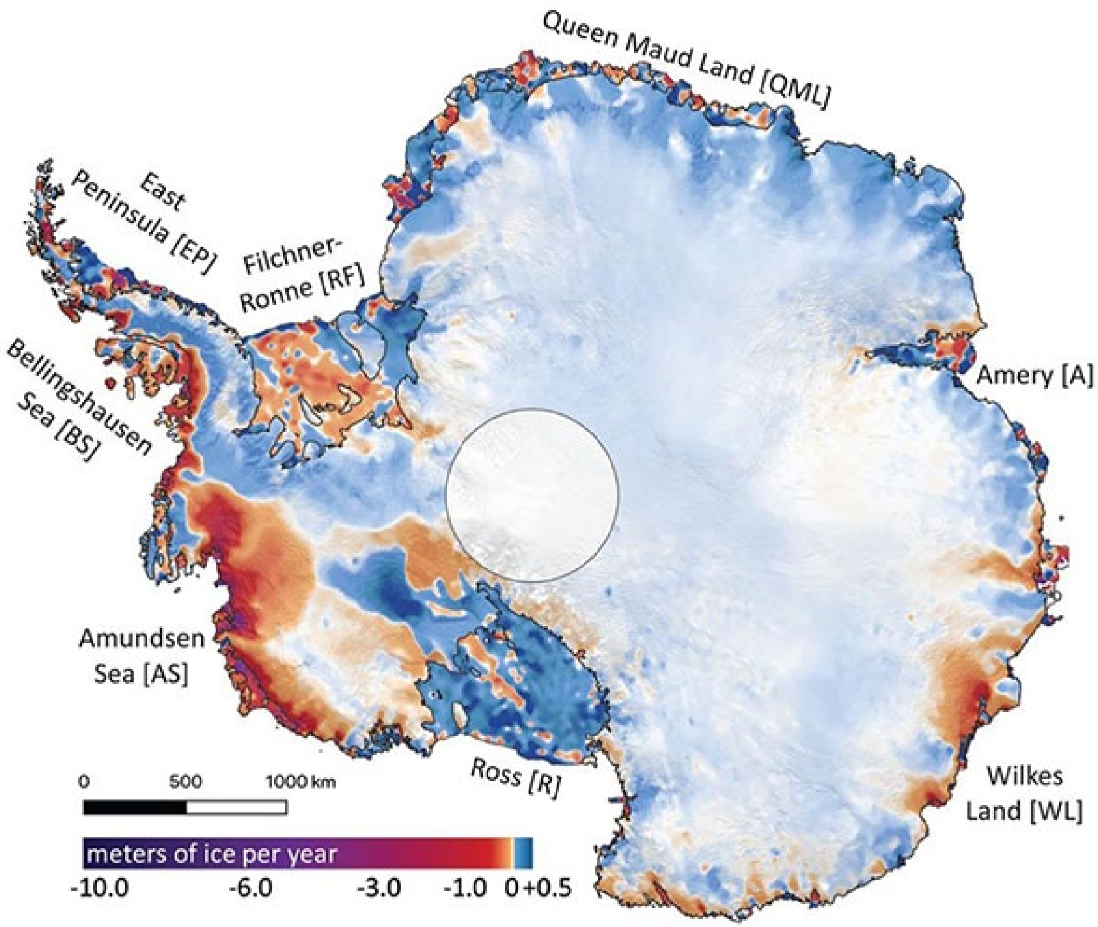

Figure 2. Ice mass loss in Greenland and Antarctica [4]. Areas that are red are losing mass and the ice surface is thinning.

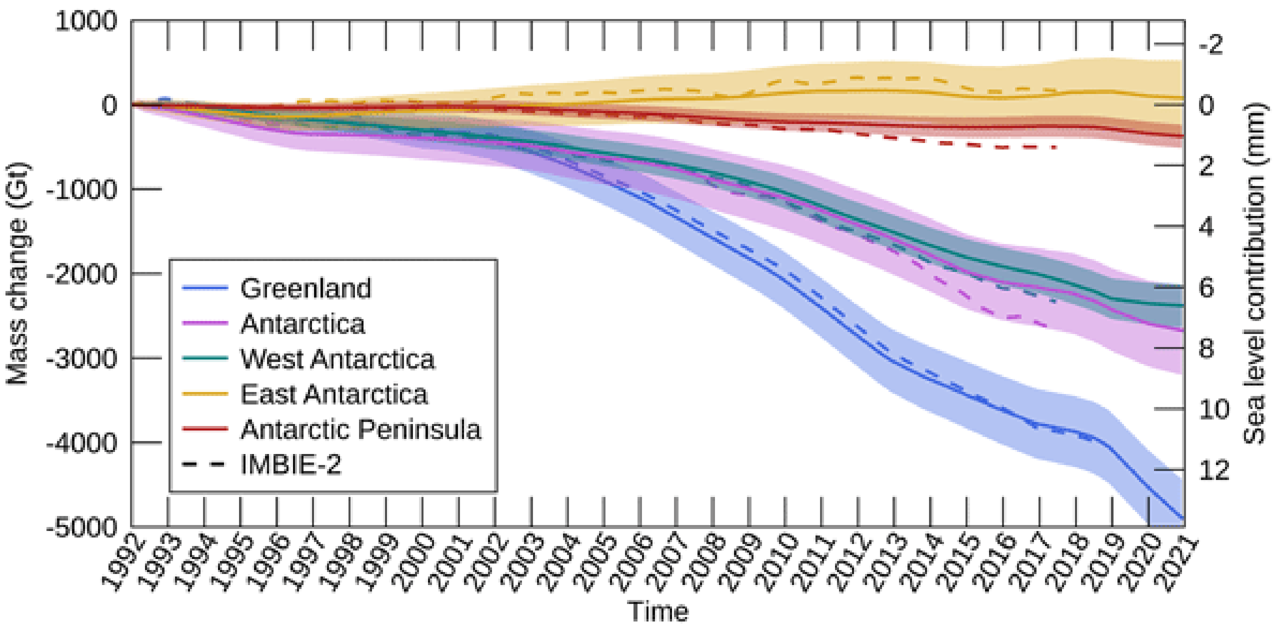

Figure 3. Ice loss from Greenland and Antarctica [3]. The mass change in Gigatonnes (Gt) on the left-hand axis is translated into global sea level rise on the right hand axis.

The Antarctic ice sheets are susceptible to a tipping point, after which further ice loss become inevitable and irreversible [5]. The tipping point in West Antarctica arises because the ice here rests on bedrock that slopes downwards from the coast inland (Figure 1). This allows water to eat away at the grounding line (the point where ice floats). This can potentially become unstable, with grounding line recession accelerating sharply, discharging more land ice into the ocean, and raising sea levels. There are also marine basins in East Antarctica that may be susceptible to this but are not currently undergoing such rapid recession. As the melt processes accelerate, loss of significant sectors of the ice sheet cannot be stopped or reversed until either temperatures are well below pre-industrial levels, or much of the ice sheet has flowed into the ocean.

The threshold for this occurring is around 1°C to 1.5°C of warming [5].

Changing sea ice extent

We have been observing the extent of sea ice continuously since 1978, and this has been daily since 1984 and Figure 4 (a) shows the extent of sea ice in the Arctic over the course of a year, and Figure 4(b) shows the extent of sea ice in Antarctica. In the Arctic the climatological mean extent typically ranges from a maximum of ~15.5 million km² in winter (March) to a minimum of ~6.3 million km² in summer (September). The ice that survives more than one summer goes on to become multiyear ice and is thicker. In the Antarctic the climatological mean extent is greater and typically ranges from a maximum of ~18.5 million km² in winter (September) to a minimum of ~2.8 million km² in summer (February). Clearly the range of extent of sea ice is greater in the Antarctic (almost 16 million km²) compared with the Arctic (~9 million km²) and so there is more multiyear ice in the north.

Climate signals from planetary warming have not propagated so coherently to Antarctica and the sea ice extent has been more variable than in the Arctic. Observations up to 2016 showing a gradual increase in extent [6], but since then there has been four record breaking minimum extents, and the winters of 2023 and 2024 have had exceptionally low sea ice extent compared with our climatological data. These low sea-ice extent events in recent years were remarkable and outside anything observed in the satellite period. It is possible the cycle of Antarctic sea-ice growth and decay has entered a new and more variable state [7]. Antarctic sea ice extent is likely to decline further over the 21st century [8].

Decreased sea ice extent will likely contribute to polar amplification of climate change, leading to increased warming due to the lower albedo [5], and exacerbating loss of land ice. Decreased sea ice will also impact krill and Antarctic ecosystems.

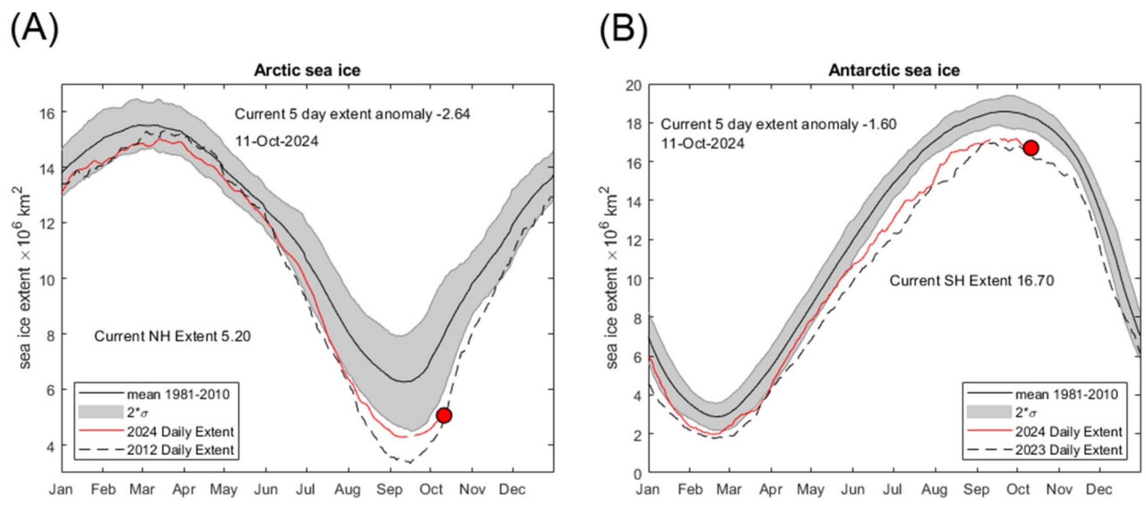

Figure 4. The extent of sea ice in the Arctic (A) and the Antarctic (B). Note the different vertical scale on each plot. The solid black line is the mean extent for each day between the period 1981-2010. The grey shaded region is where we could expect the sea ice

extent to be. The red line is the extent for 2024, and the black dashed line shows the extent for the year when the lowest sea ice extent was recorded. (A) The Arctic and the extent was lowest in 2012), and (B) The Antarctic, and the lowest extent was measured in 2023.

Sea level rise and implications for the UK

As a result of these land-ice processes, global mean sea level will rise by 2-3 m if warming is limited to 1.5°C, 2-6 m if limited to 2°C and 19-22 m with 5°C of warming, and sea levels will continue to rise for millennia [9-12]. Gravitational influences on sea level rise may mean that sea levels rise faster in far-field locations like the mainland UK and US East Coast [13, 14]. This rise in sea level will mean that current 1-in-100 year coastal flood events will occur at least annually in half of all tide gauge locations worldwide [15].

Coastal flooding is one of the top four priority risks for the UK Government, with estimated annual damages of £540 million in 2017 [16]. With global coastal populations of >600 million, any level of sea level rise will impact and potentially displace large numbers of people [17]. Estimates of globally displaced populations vary considerably but could many millions of people by 2050 [18].

Sea level rise of this magnitude will severely impact Britain, including greater incidences of coastal flooding and increased severity of winter storms, but also through likely increases in population displacement from other countries negatively impacted by rising sea levels. Coastal flooding will impact coastal communities, including low-lying ports and facilities. Notably many of the British Overseas Territories (with a collective population of 250,000 people and often with unique and important ecosystems) are composed of low-lying islands vulnerable to sea level rise (e.g. Bermuda and the Cayman Islands, with the majority of the population; British Indian Ocean Territory).

2. What effect is climate change having on biodiversity in Antarctica?

Ecosystem services are defined as the goods and services provided by ecosystems to humans. Polar marine ecosystems are changing, impacting the services they provide, due a combination of global environmental change and direct human contact [19]. Native organisms, from the plankton to top predators, are shifting poleward and becoming vulnerable to non-native species. Changes to ocean temperatures, sea and glacial ice, and ocean chemistry are the primary drivers of ecosystem change. Human activities in both polar regions increase the risks and impacts of climate change including unsustainable harvesting, the introduction of non-native species, pollution, and disturbance [19, 20].

The Southern Ocean, surrounding Antarctica, is seeing impacts upon key and commercially valuable organisms such as Antarctic krill (*Euphausia superba*). Krill are important to various ecosystem services, including a commercial fishery worth over 200 million US dollars per year and as a major food source for predators such as whales, seals and penguins that attract tourism [19]. Krill are dependent on winter sea ice as a nursery for their young and are threatened by the recent record-breaking sea ice declines.

The remote, cold and isolated nature of Antarctica has prevented many non-native species reaching its continental shelf for millions of years. Now Antarctica has visitors from all over world and the route for harmful invasive marine species has been radically shortened to a few days of ship time, compared a journey that would take natural floating objects such as kelp or wood years to reach Antarctica [21]. As the climate changes the pressures on the Southern Ocean and Antarctica are increasing (Figure 5).

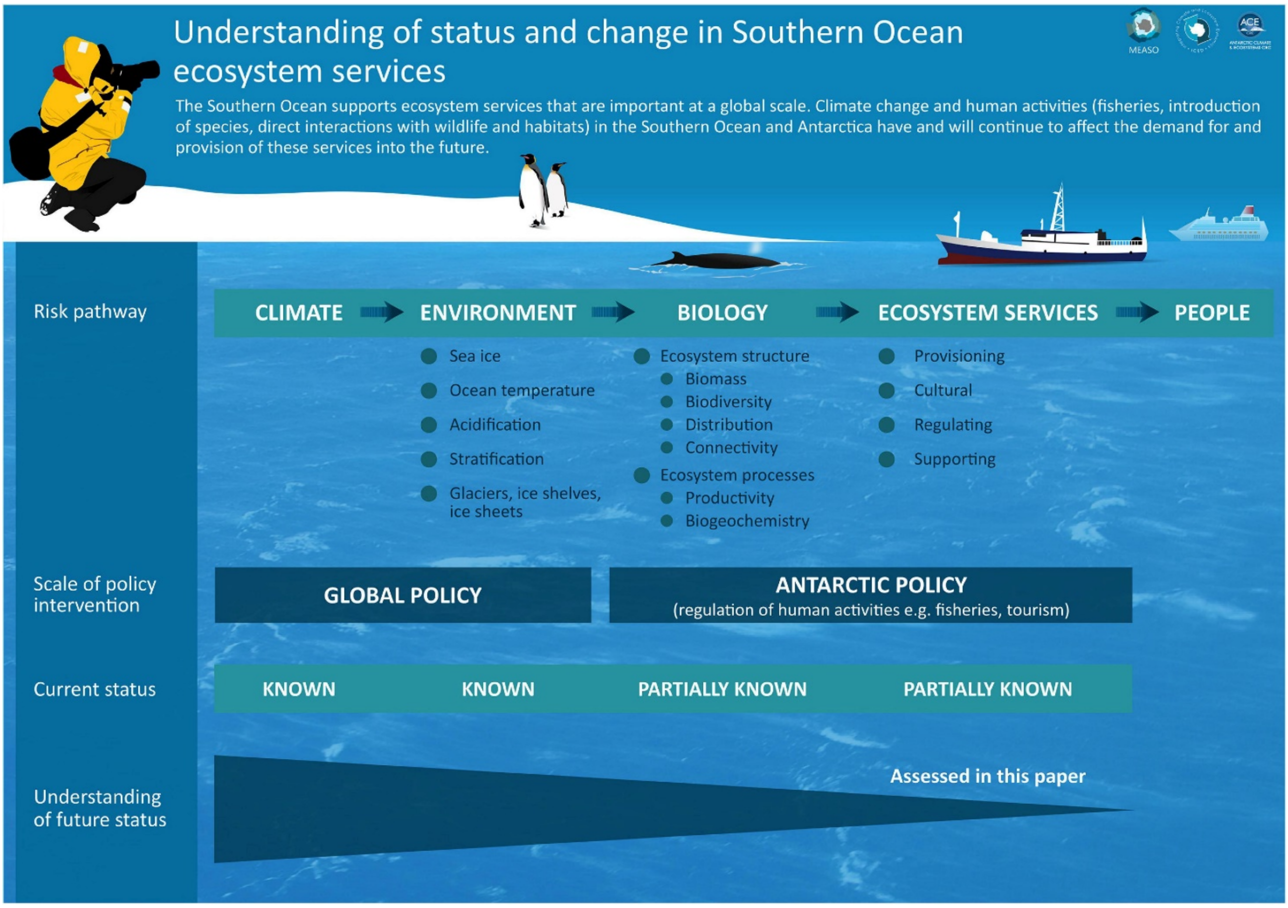

Figure 5. Key risk pathways affecting Southern Ocean ecosystem services, from climate change impacts on physical drivers through to biological impacts and on to the benefits obtained by humans. The variables listed under 'Environment' and 'Biology' are examples of the wider suite of variables that could be affected [19].

5. How well placed is the UK to deliver scientific priorities identified by national and international research communities?

The future of ice mass loss from the polar ice sheets is uncertain[22]. Numerical models need to be set up, tested and trained with observations of past ice-sheet behaviour, especially across different climate states and environments. Improving ice-sheet projections requires the following: firstly, have excellent data for setting up models (such as ocean bathymetry, geophysical surveys of grounding lines, surface mass balance measurements, bed topography measurements and climatic observations) as well secondly, data that constrains the behaviour of the ice sheets under past climates (such as geological samples and mapping). Facilities from the British Antarctic Survey, including the *RRS Sir David Attenborough*, are essential for gaining access to geophysical, biochemical, marine and geological datasets that are essential for informing and validating these models.

The UK must act collectively and in partnership with the international community and collaborate with international research organisations in order to achieve the potential for Antarctic research[22].

6. How well does the UK support research in and about the Antarctic, and what can the UK do to position itself at the forefront of Antarctic science?

Increased support could include increased polar logistical support to enable research activities in polar regions. Helicopter support is increasingly needed as scientists seek to visit more inaccessible areas to gather essential data to constrain and inform numerical models. Currently it can be difficult to schedule time on the SDA, even years in advance, and obtaining support for planned fieldwork is challenging due to logistical constraints. Increased polar logistical support is necessary for the UK to remain at the forefront of Antarctic science.

There is growing interest in geoengineering solutions in Antarctica to mitigate the impacts of warming ocean currents on sea ice, ice shelves and the grounding lines of glaciers [23-25]. Most scientists view these efforts as an expensive distraction from efforts to attain 'net zero' and unlikely to address the underlying of planetary warming [26]. Currently, these geoengineering solutions are likely to cause significant environmental damage, and have the possibility of grave unforeseen consequences. These solutions would cost $100s of billions with decades of ongoing maintenance, which is unlikely to be secured within the short timescales necessary to avoid climate change.

As a founding signatory of the Antarctic Treaty, it is imperative that we conduct Antarctic research in a manner that protects the environment[22]. Careful management, leadership and governance under the terms of the Antarctic Treaty will increasingly be needed to safeguard the polar regions and ensure that any mitigation measures are undertaken in the best interests of the polar regions, without unintended consequences, and following the best practice as outlined by the scientific community in the peer reviewed literature.

8. How does HMS Protector benefit UK Antarctic science and how can her contribution be maximised?

The Antarctic is a challenging long-distance operating environment for the UK with HMS *Protector* moving north and south on a seasonal basis. The RN work closely with the UK science operator British Antarctic Survey (BAS) and the polar vessel, *Sir David Attenborough*. The Royal Navy plays a vital role in charting and mapping, environmental monitoring, base inspection, combatting illegal fishing and making visible the British presence. The UK's armed forces more generally contribute to the operational reach of BAS and contemporary science depends on helicopters and drones for access to remote and difficult to reach environments. Unlike the Arctic, the Antarctic is not subject to territorial and jurisdictional control, so all parties have freedom of investigate across the region. The Antarctic Peninsula is the most congested part of the Antarctic in terms of science stations and visiting tourists. The UK territorial claim overlaps with Argentina and China and this could be used by others to ferment discord both north and south of the Antarctic Circle.

The scientific need for oceanographic surveys is serviced by Royal Navy and royal research vessels, and this involves deploying and uplifting scientists to and from remote and challenging environments to collect observational datasets. These datasets can be used to evaluate models against past periods of rapid change and help to improve the model set up and training. Logistical support from the Royal Navy for field deployment of scientists, installation of equipment to support multi-season campaigns and support for increased surveying, would be essential for gathering the data needed to improve projections. The polar capabilities of the Royal Navy, which exceed those of most civilian operators, will be essential for this work.

Changing sea ice conditions can make surveys and field logistics challenging, as well as the remote nature of polar fieldwork, especially given an increasingly unpredictable environment that is susceptible to extreme events [27]. Military capability and skillsets, alongside a range of polar vehicles, is necessary to achieve this objective.

HMS *Protector* also has a role as an ice patrol ship. She is deployed for a three-to-four-month period to Antarctic waters every year and has worked closely with the Australia and New Zealand Navies on the problem of illegal, unreported and unregulated fishing. HMS *Protector* also assists with ecological and biological surveys and provides logistical support to scientists monitoring Antarctic flora and fauna.

10. What further action is needed through the Antarctic Treaty System to protect the Antarctic?

The environmental protection and governance frameworks of the Antarctic Treaty System needed to safeguard polar regions, and to avoid significant environmental consequences, are under severe stress.[1] The Antarctic Treaty (1959) and associated legal instruments such as the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) are being challenged by two countries in particular, China and Russia. The latter have proven themselves to be most reluctant to embrace any expansion of marine protected areas in the Southern Ocean and have actively contested attempts to regulate further krill fishery management. The 2024 annual meeting of CCAMLR parties was widely judged to be a failure and concern was expressed that China and Russia are hard wiring their opposition to the fundamental principles of CCAMLR such as precautionary behaviour and using the “best scientific evidence available”. All of which matters because at its heart the Antarctic Treaty System relies on consensus, collective self-restraint and a willingness to place scientific evidence at the heart of decision-making.

For the UK and other allies, there are several immediate actions to be taken.

First, the UK should publish its Antarctic strategy and within that there should be a clear statement about why the rules, norms and values of the Antarctic Treaty are important not only to UK but wider global interests. No one should wish to see the Antarctic be militarised or exploited irresponsibly.

Second, there is evidence the EU is reconsidering its approach to Antarctica and the UK and others should work with EU partners to generate a pan-European coalition of scientific research generation and information-sharing. One way to challenge China and Russia is to double-down on the generation of “best evidence”.

Third, if China and Russia refuse to work with others on MPAs then other parties should consider hitting the “pause” button when it comes to establishing annual fisheries catch limits including krill, even if it affects the commercial interests of the UK (South George) and Norway (the largest exploiter of krill).

Fourth, the Antarctic Treaty parties need to be clearer on how they are going address the spectre of dual-use technologies and re-commit to the underlying principles regarding the peaceful use of Antarctica. The US did carry out an inspection of the newest Chinese Antarctic station and reported on it in February 2020. The treaty was written in the late 1950s, and this aspect needs readdressing.

Finally, there are very real concerns about Russia’s behaviour in Antarctica. Russia has used the polar marine geosurvey expedition and vessel *Alexander Karpinsky*, both controlled by Rusgeo (a state geological company), to carry out seismic surveys of regional Antarctic seas. In one statement released in 2020, the company noted that based on their surveying work, they thought that ‘potential hydrocarbon resources in

[1] https://committees.parliament.uk/writtenevidence/124548/pdf/

the identified sedimentary basins are estimated at approximately 70 billion tons'. The UK and allies should demand that Russia reaffirm its commitment to the permanent mining ban and share further information about the future voyages of the *Karpinsky.* Russia has also proved to be a thorn in the UK's side by refusing to endorse fishing catch limits in and around the island of South Georgia. The UK ignored Russia's provocation and issued fishing licences which provide vital revenue for the UK territory's government in South Georgia. The net result was to anger the US who criticised the UK's unilateral action.

The net-result of all of this is that the UK needs to be alive to the fact that the Antarctic environment is likely to become ever more strategic and competitive.

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